

# **GERB Instrument: Operation, Data Collection and Calibration status**

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# GERB operation summary

Currently all four GERB instruments are in orbit and still capable of operating nominally

**GERB1:** Recovered from the most serious mirror anomaly so far observed.

**GERB 2** Now at 41.5 E. Special scan mode investigated to overcome calibration offset between mirror faces and enable reconstruction of noisy pointing data obtained for 6 months when satellite position information compromised.

**GERB 3:** Now in SAFE. Increasing running outages during 2017 but recovery always achieved. Mirror side calibration differences under investigation to enable science processing for 2015-2017

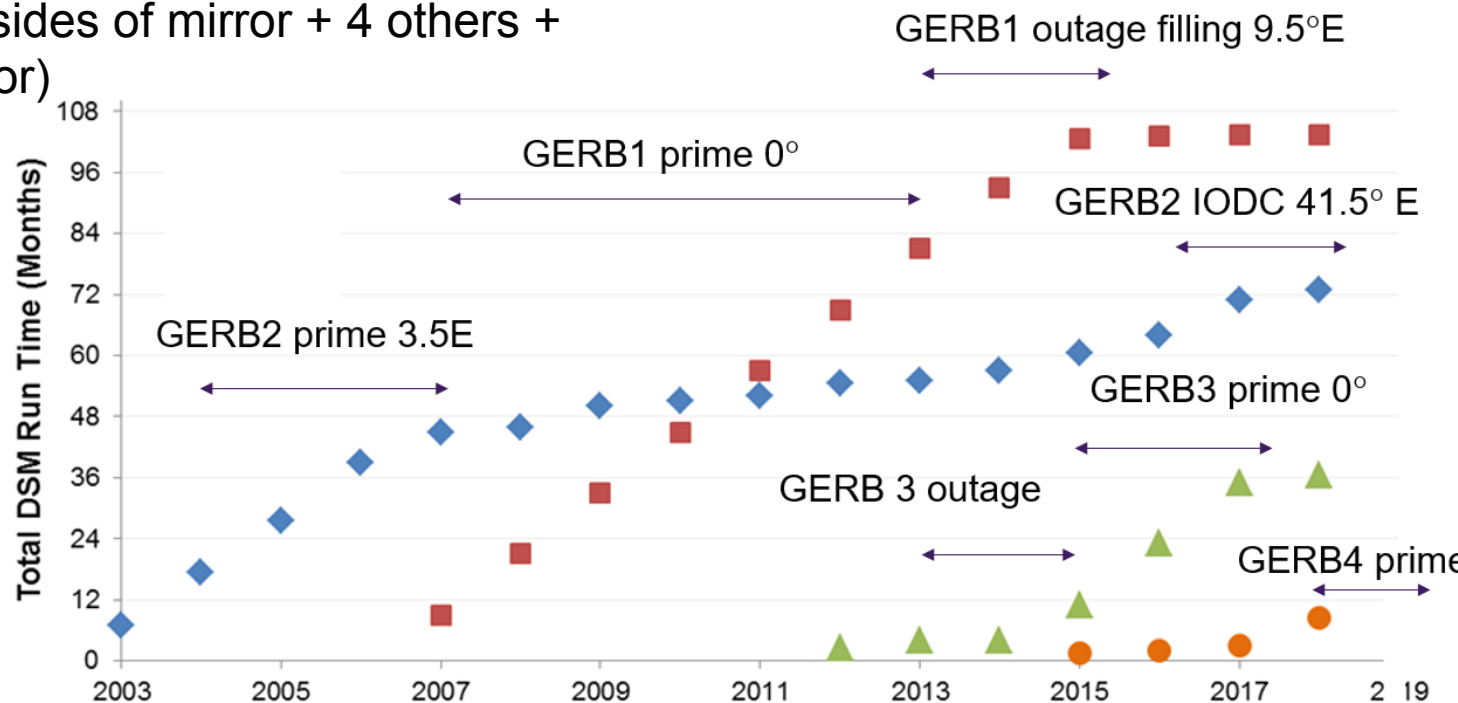
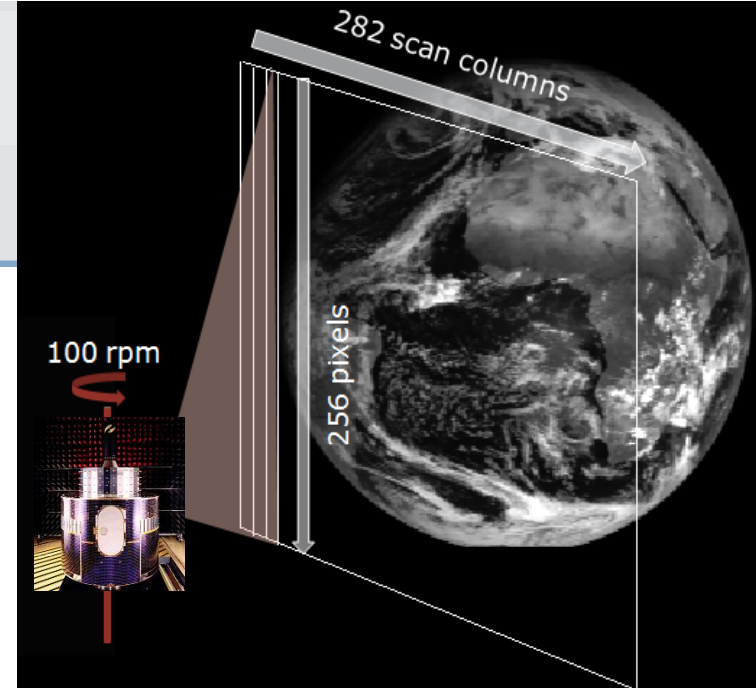
**GERB 4** became prime operational instrument at 0° Feb 2018 awaiting final issue of calibration parameters and soon to being NRT processing.

# GERB operation

GERB's scan mirror counters satellites 100rpm spin by rotating at 50rpm in opposite sense. Graphite lubricated bearing operating under 16g GERB's main **life limiting mechanism**.

Good data requires:  
accurate information from the satellite on its spin  
Precise mirror control  
Good calibration (2 sides of mirror + 4 others + quartz filter + detector)

On broad calibration broadband.  
Spectral aging of the mirror needs to be derived by other means



# GERB 4 operations

- GERB 4: prime operational instrument at 0° since Feb 2018
  - 5<sup>th</sup> Jan – 12<sup>th</sup> Feb Move to prime position at 0°
    - » Cross cal data collection with GERB-3 (> 97% successful coincident data collection)
    - » 2 CALMON scan, 4 lunar observations, zero step mirror side
  - 18<sup>th</sup> Feb – 25<sup>th</sup> April Sun avoidance period [drive control latch up event]
  - 25<sup>th</sup> April – present Prime operation (+CALMON & lunar scans, satellite SEU)
    - » CERES PAPS scan intercomparing operation (June)
    - » GERB 1 activation for cross calibration (~35% successful coincident data collection)

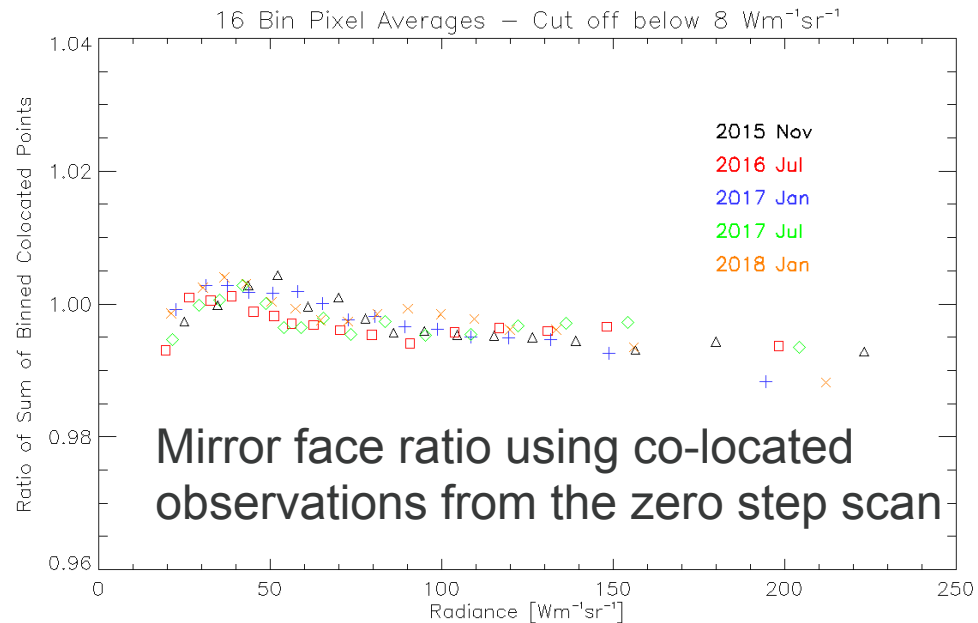
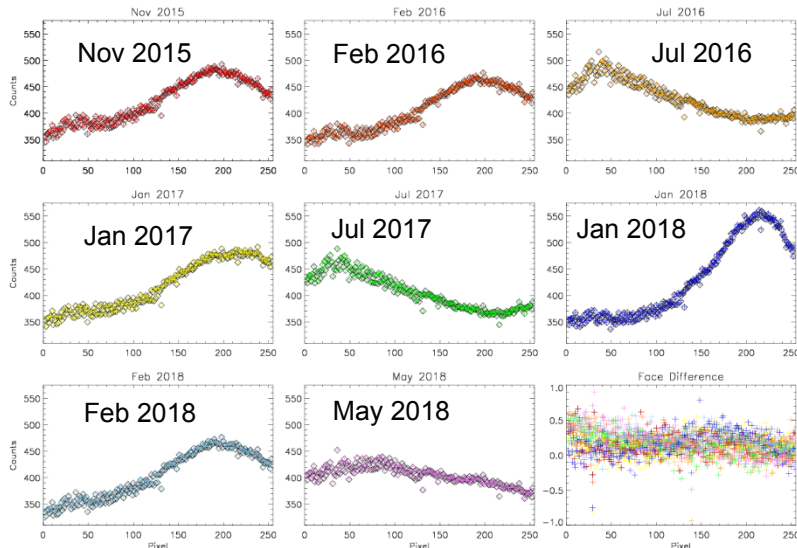
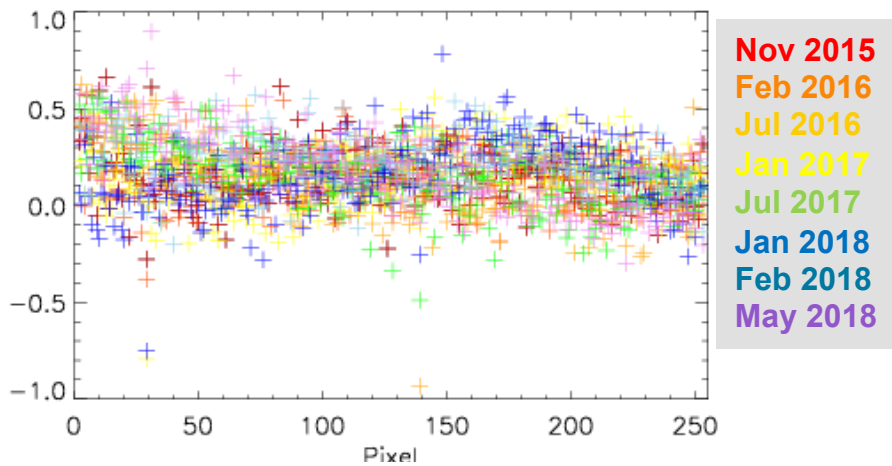
**Mirror control:** In early commissioning GERB 4 exhibited severe mirror control errors, tracked to control circuit miscommunication at satellite spin speeds above a threshold. Solved by small decrease in satellite spin speed mirror control is now nominal. Nominal control very good and bearing running smoothing since activation in 2018 (12 mirror pointing anomalies and 63 mirror torque excursions in ~19 million satellite rotations, only one pointing anomaly associated with a torque excursion (this is considerably better than GERB 3).

**Mirror aging:** GERB-4 prolonged in orbit storage. In orbit storage mirror park has been successful: no evidence of differential drift between the two mirror faces.

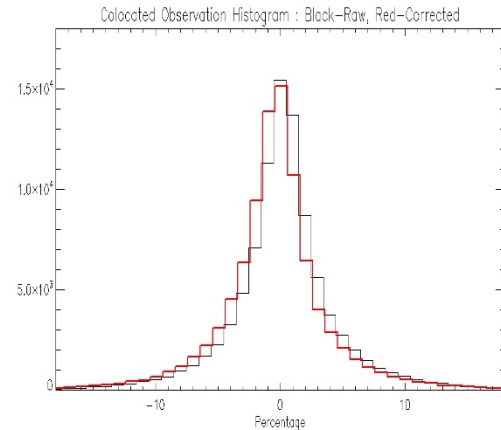
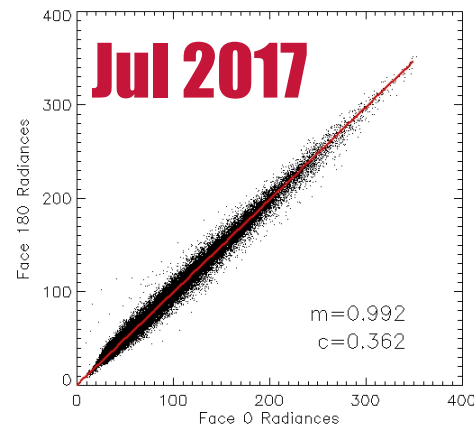
GERB-4 will remain the primary instrument for the foreseeable future NRT products expected by end of year.

# GERB-4 IOS : Earthview Mirror Face Evolution

## CALMON mirror face difference



Mirror face ratio using co-located observations from the zero step scan



# GERB-4, 1 Observations : May-June 2018

GERB-1 was activated on the 29<sup>th</sup> May to begin imaging from the 30<sup>th</sup> to the 26<sup>th</sup> of June during full Earth imaging with SEVIRI on MSG2.

GERB-4 was Earth imaging through the entire period.

Due to a number of complications GERB-1 imaging was *interrupted*.

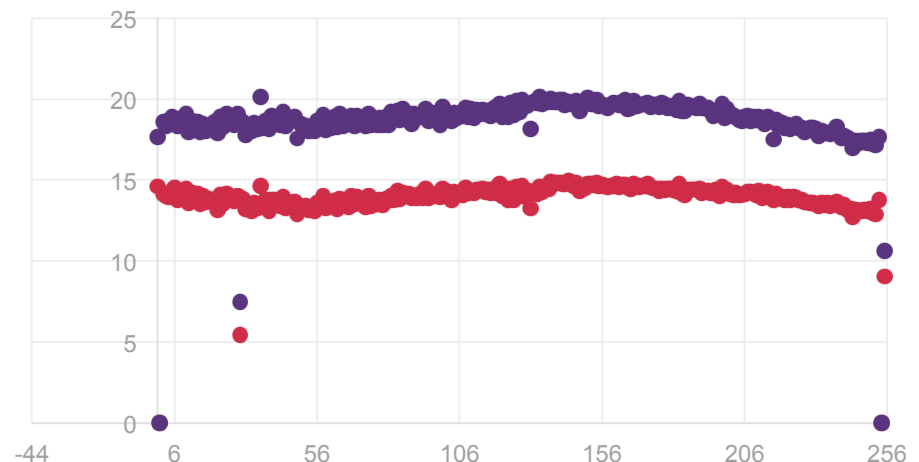
30/05	09:30	Antenna inoperative, Satellite SAFE mode	18/06	03:55	Deep Space checks tripped
05/06	11:24	Imaging	18/06	08:56	Imaging
08/06	00:30	Rough DSM running	19/06	08:24	Rough DSM Running
13/06	11:26	Imaging	21/06	10:11	Imaging
14/06	12:57	Rough DSM running	26/06	08:10	IOS resumes

From a target of 27 days data a total of 9.5 was gained. A possible mitigation for the majority of this data loss is a longer run in time, this was not possible on this occasion due to operational constraints from the EUMETSAT side.

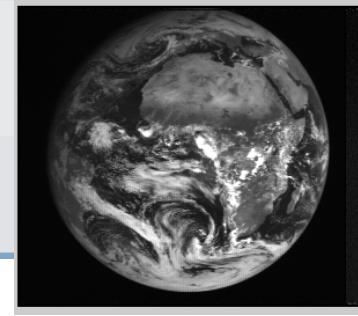
# GERB 4 ground cal parameters

- Delay in delivering these for launch due to manpower issues
  - Long in orbit storage period for GERB 4 meant that commissioning calibration funding wouldn't be activated at launch (2015) but in 2018
    - » Launch tables copied from GERB 3 for test processing
    - » GERB 4 calibration presented some unique finding with much lower response to LW scenes than other GERB instrument (about half) hence higher noise
    - » Ground calibration indicates difference coming from lower detector response at the longest wavelengths (response inferred from data observing temperature range of reference black bodies +70 to -50°C)
    - » SW portion of the response similar to other GERB instruments

*Expect to start test processing with GERB 4 cal parameters next month  
All being well NRT GERB-4 products should become available early next year.*



# GERB 3 operations

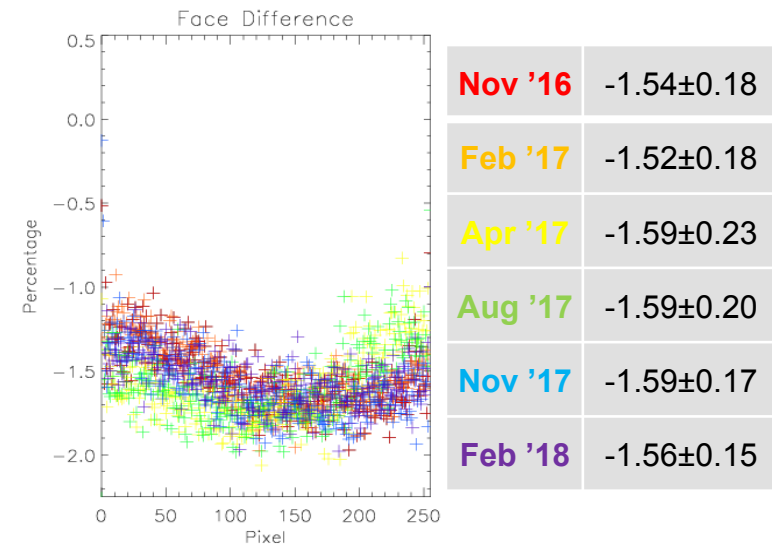
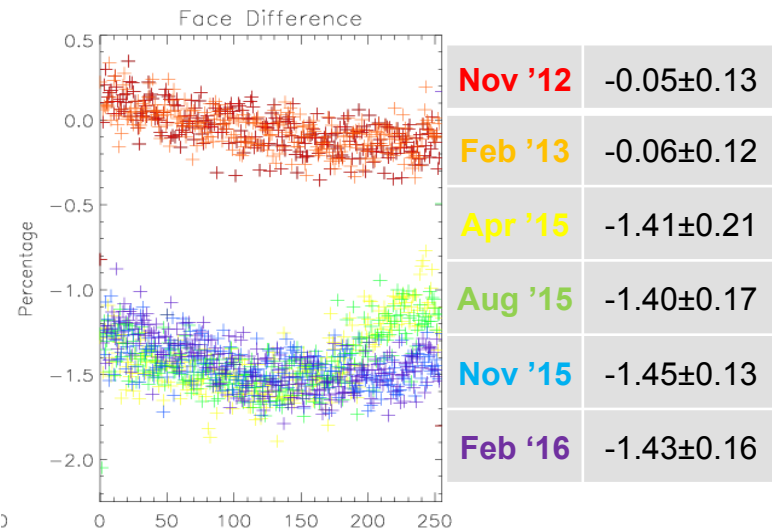


- GERB 3: from prime operational at 0° to in orbit storage at 9.5°E
  - Feb 2013 – Jan 2018 prime operational configuration at 0°
    - » Instrument operating anomaly [outage April 2013-April 2015](#) (resulted in differential aging of the two mirror sides)
    - » Nominal operational April 2015 – Feb 2018. NORMAL mode with exceptions for calibration scans, mirror events, Sun avoidance and other outages. [Mirror side calibration difference requires processing modifications to produce science quality products](#)
    - » Safety transitions due to mirror rough running continue and have increased from ~ 1 per month to ~ 1 per week, majority easily recovered but more serious occurrences occurring more recently have needed more protracted recovery operations. Pattern of increase similar to GERB-2 but drive differences mean recovery more interactive with GERB-3
    - » New operating 'mirror toggle procedure' (SC\_GB022) has been useful in freeing the mirror. Still some margin in available torque used to free mirror (full speed with torque ripple reject enabled).
  - Feb 2018 – present In orbit storage in SAFE mode
    - » [scan mirror parked 'edge on' at 67° to avoid storage aging](#) (position used since it's long outage and now shown successful for GERB-4 in orbit storage).

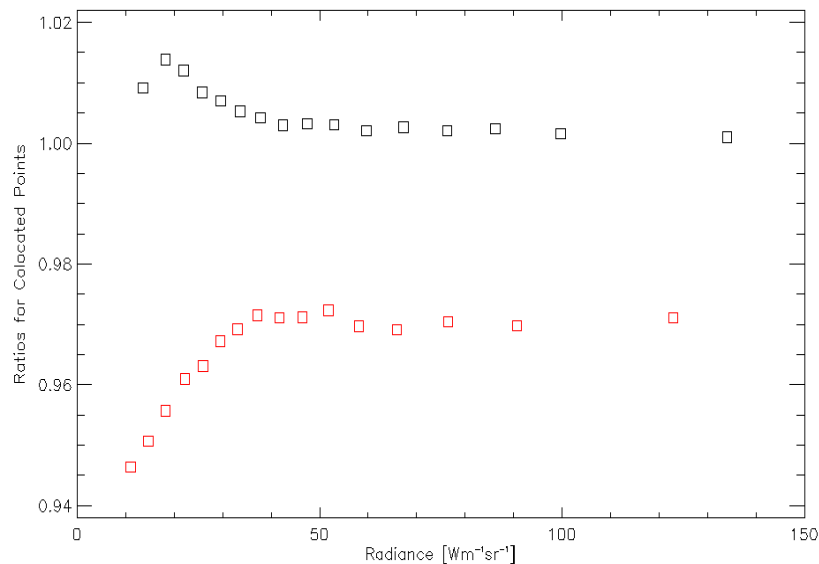
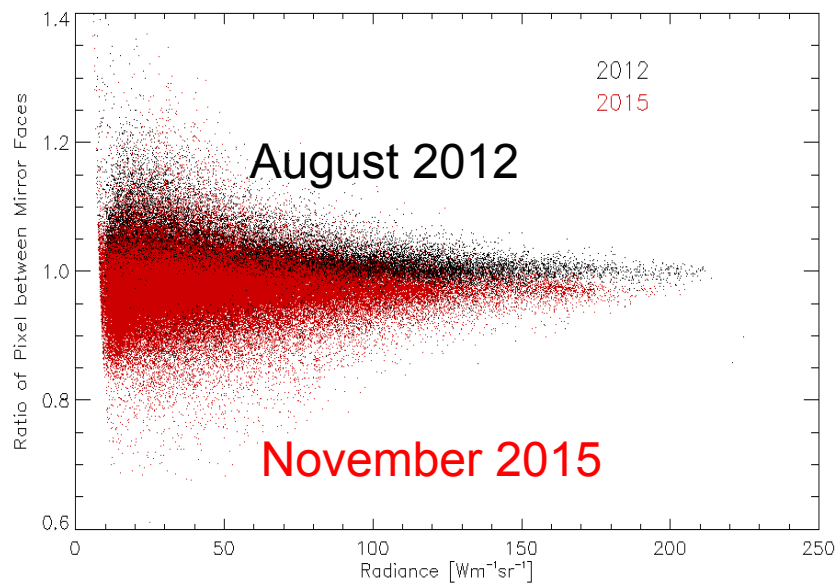


# GERB-3 Mirror Face ratios before and after outage

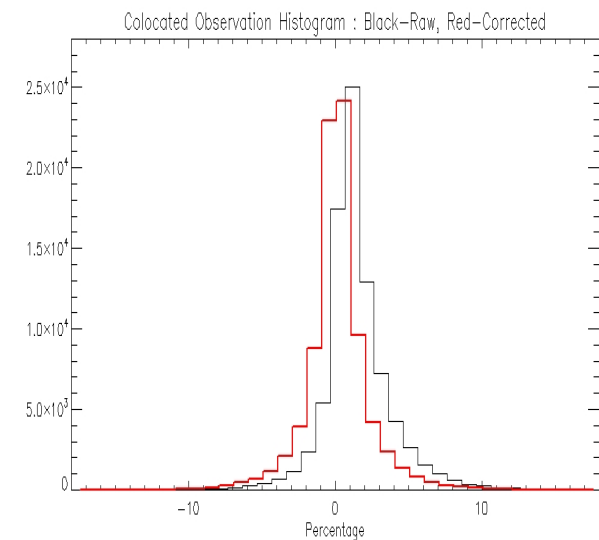
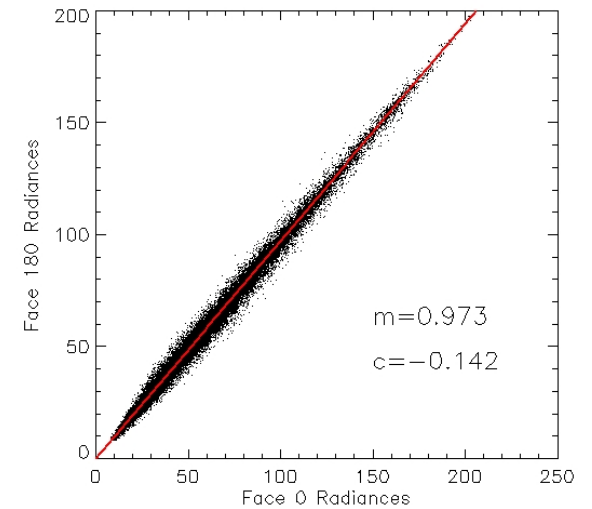
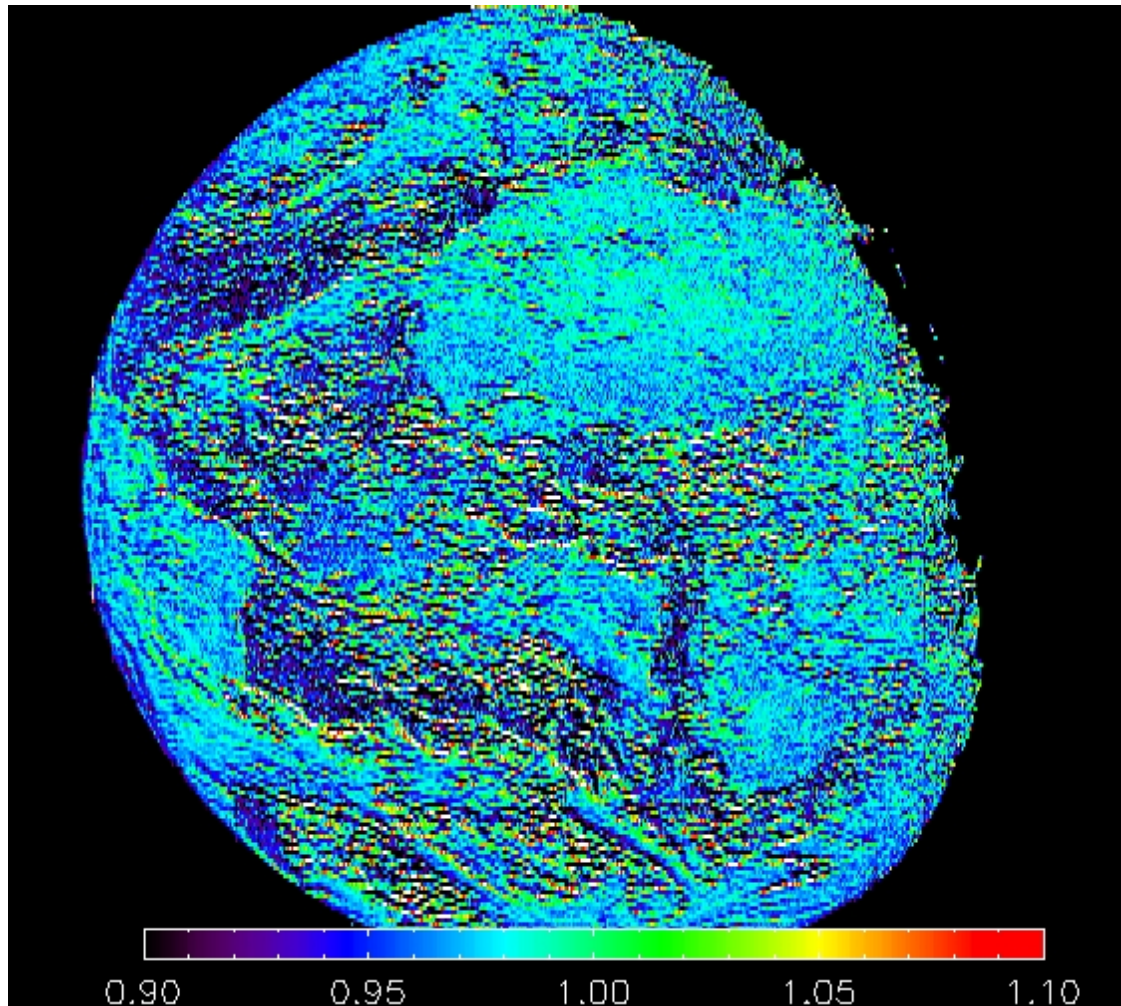
## CALMON observations



## Earth observations



# GERB-3 Mirror Face differences



# GERB-3 DSM Incidents by Severity

GERB-3 DSM incidents graded into categories based on their severity.

- **1: Major mispointing self-recovered within 3 rotations:** mirror remains rotating EUMETSAT operator returns to NORMAL. **Few minutes data loss.**
- **2: As 1 but not recovered in 3 rotations cleared by backward rotation restart:** Imperial ops intervention to monitor backward rotation recovery. **Few hours to days data loss.**
- **3: As 2 but not cleared by backward rotation, requires toggle procedure.** Imperial ops intervention to monitor and execute recovery. **Few hours to days data loss.**
- **4: As 3 but multiple toggles and possible special modes to increase torque.** Imperial ops intervention to monitor and execute recovery plus higher level agreement for additional modes. **Several days plus data loss**

GERB-3 mirror events increasing in frequency and severity over time

Ccategory	1	2	3	4	5
May '15 – Jun '17 (25 month)	13 (0.51)	5 (0.2)	1 (0.04)	2 (0.08)	0 (0)
Jun '17 – Feb '18 (7.5 months)	9 (1.16)	7 (0.9)	4 (0.52)	5 (0.65)	1 (0.13)

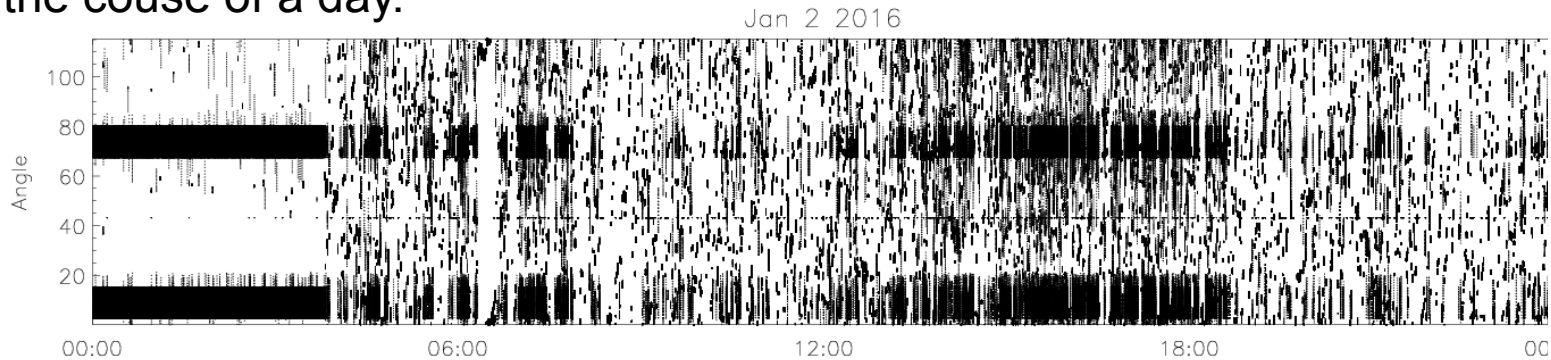
C.F. GERB-2 with first sticking incidents at ~ 18 months rising in waves from then

# GERB 3 summary

- GERB 3 operational record 2015-2017 and now in SAFE. Accumated just 3 years running and we hope it has a lot of life left for future operations in the MTG era.
- GERB 3 with a new improved drive system was an operational learning experience!
  - When working well the accuracy of the pointing is noticeably improved over the other GERB instruments with less jitter and bad scan lines.
  - However Instrument requires more operator intervention to deal with mirror running issues
  - Several new procedures have been developed over the last few years
  - Also drive discovered to have a start-up weakness that makes power cycling more risky than for other GERB instruments.
- Start up weakness resulted in 2 year outage and subsequent differential aging of the mirror
  - However the timing early in the GERB 3 operation meant the correction could be addressed on ground for GERB 4
  - The aging has resulted in new park procedures for all the GERB instruments
  - Processing solutions to address the mirror side issues are in development

# GERB-1 Extended Pointing Failure – Jan 2016

Jan 2016 saw GERB 1 mirror position go from odd scan lines being out of position to increasing number of defect and then apparent complete loss of pointing control over the course of a day.



At 8 years of rotations (design life 3.5 years)

And not needed operationally (GERB-3 had been restarted and GERB-4 commissioned and in storage in orbit).

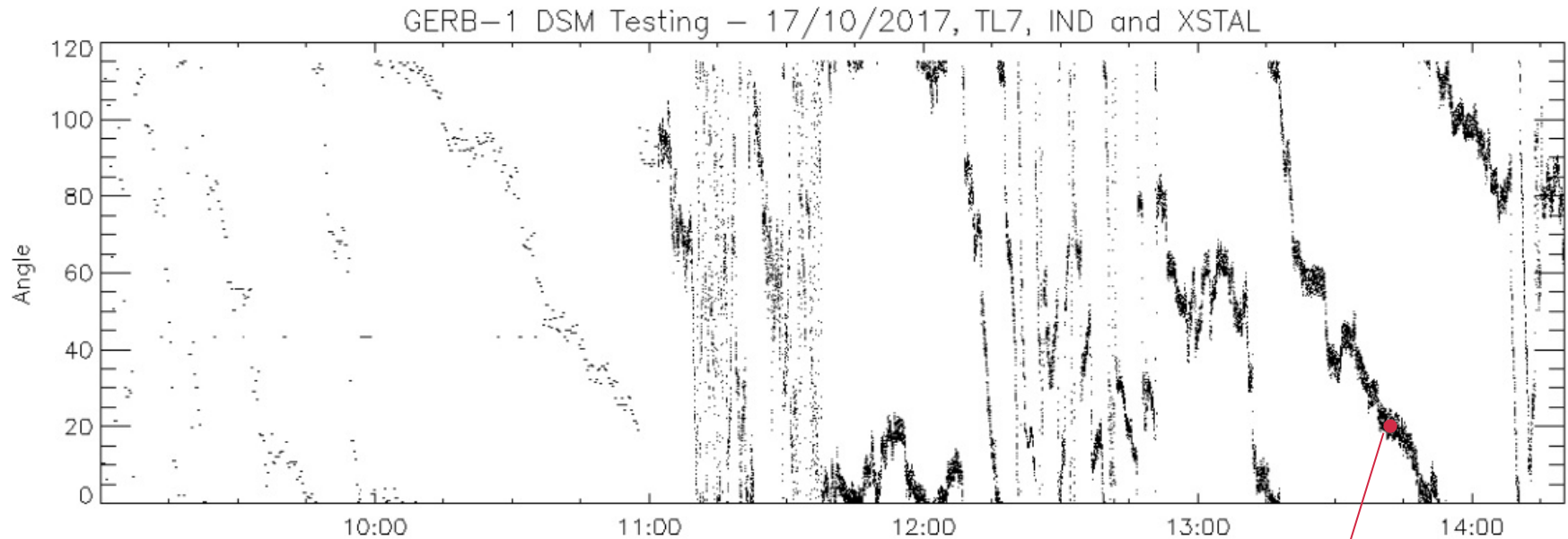
EUMETSAT support for extended experimental recovery could not be prioritised and some pressure to declare end of life event.

As this instrument may move over the Indian Ocean in future we had interest in recovering if possible and had in understanding end of life state if this was the case.

Agreed to schedule 2 weeks testing in late 2017 and then declare status with option to try restart if moved over the Indian Ocean.

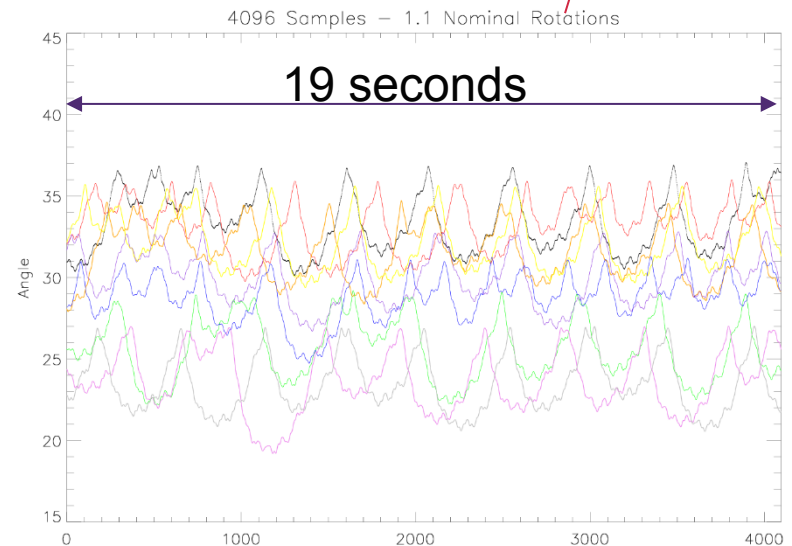


# Intensive GERB-1 DSM Oct 2017



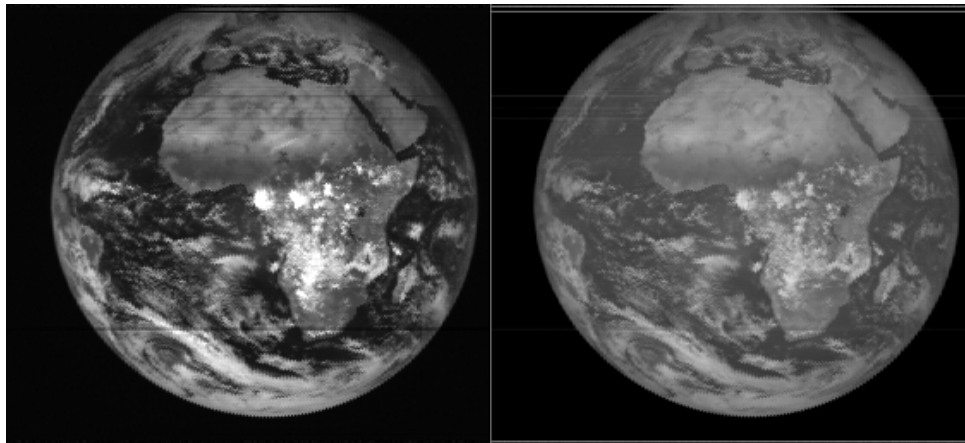
2017 extended testing of GERB 1 mirror anomaly. At maximum torque mirror exhibited only very slow *backwards* progress.

During second week of testing different non-maximum torque levels were tried and it eventually freed itself over a period of a couple of days using a mid-level torque.



# GERB-1 after Recovery

78 Images taken on the 30<sup>th</sup> October 2017. The first two and the three images with small pointing defects are shown. Torque level tests show optimal operating torque still TL2 (same as before event)

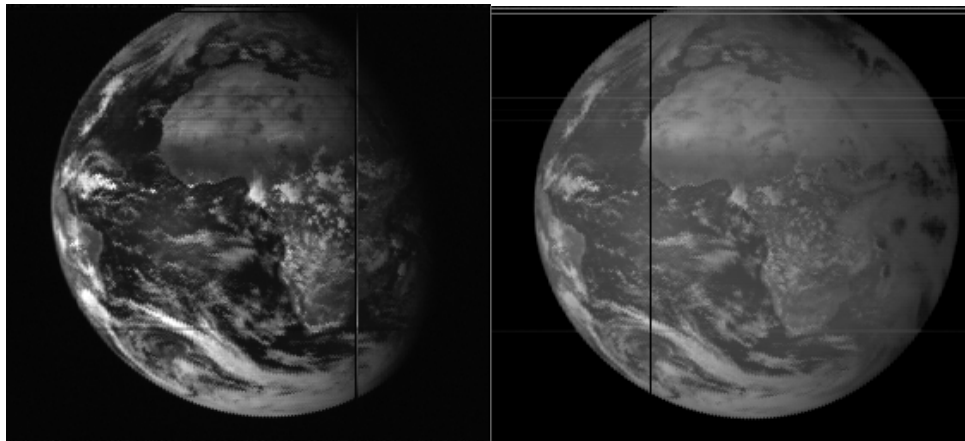


Some differential mirror side ageing seen over outage period ( $\sim 0.5\%$ ).

After six months of inactivity smooth running was preserved in reactivation May 2018. In one hour in SUNBLOCK no OOL pointing errors were observed aside from those expected at DSM start up and stop.

Another major, but more quickly recovered, event did occur during GERB-1 reactivation in June for joint operations with GERB-4.

Six monthly activations will continue



# GERB-1 summary

Nice to recover GERB-1 and have an instrument still able to operate despite accumulating over twice design life of mirror rotations (currently 8 years)

A lot was learned from the GERB-1 recovery:

- New monitoring modes were defined to observe the mirror in these uncontrolled states
- We now know that these very serious events appear to be a further stage of the bearing life
- Interesting mid levels torque for extended periods have been shown to most successful at eventually freeing the mechanism
- There is not lasting effects of performance bearing still capable of good running at standard torque level.

Parking the DSM with a target of  $55^\circ$  (to achieve a close to edge on orientation of  $62^\circ$ ) has been productive so far (parked at  $63.4$  degrees currently.)



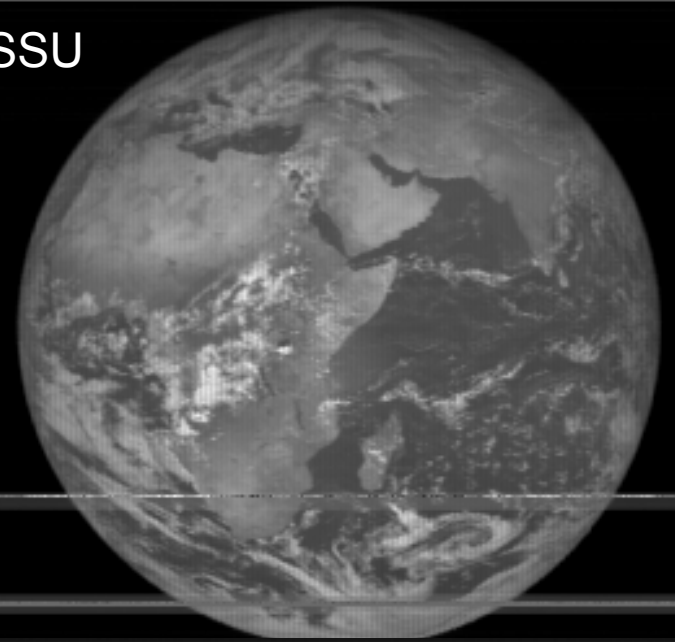
# GERB 2

GERB 2 41.5° E at 5.5 years of rotations accumulated continue until MSG-1 re-orbit in 2020.

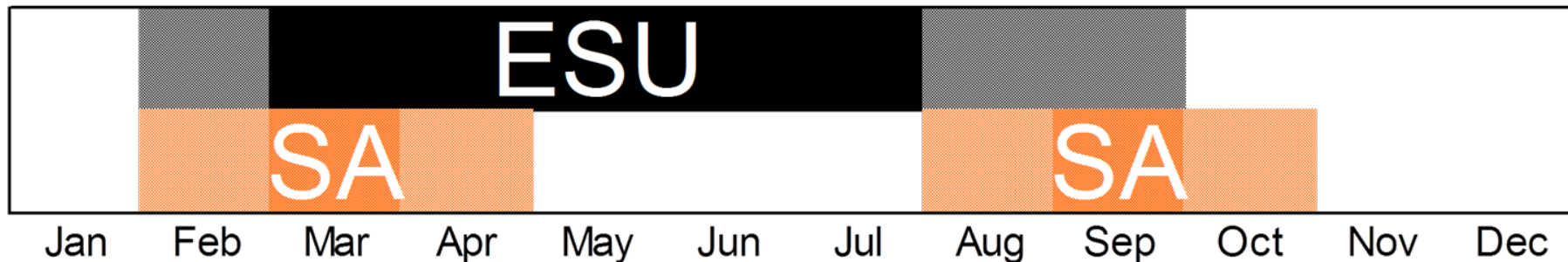
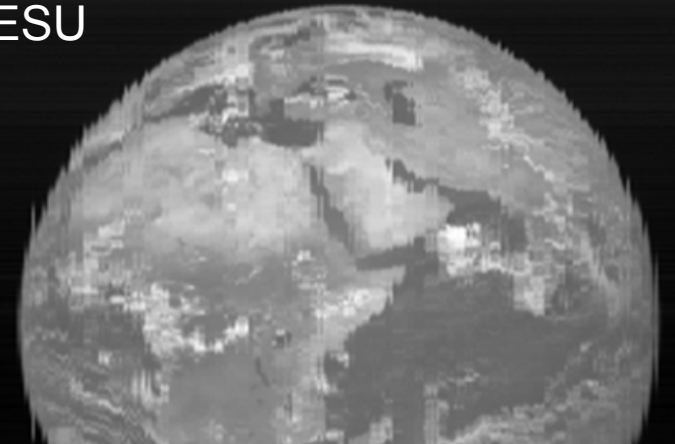
Processing updates required to enable full science exploitation.

1. Mirror side calibration difference requires processing update to treat the two sides of the mirror separately
2. Half the year satellite position information noisy due to problem with the primary position sensor. Requires analysis and processing changes

SSU

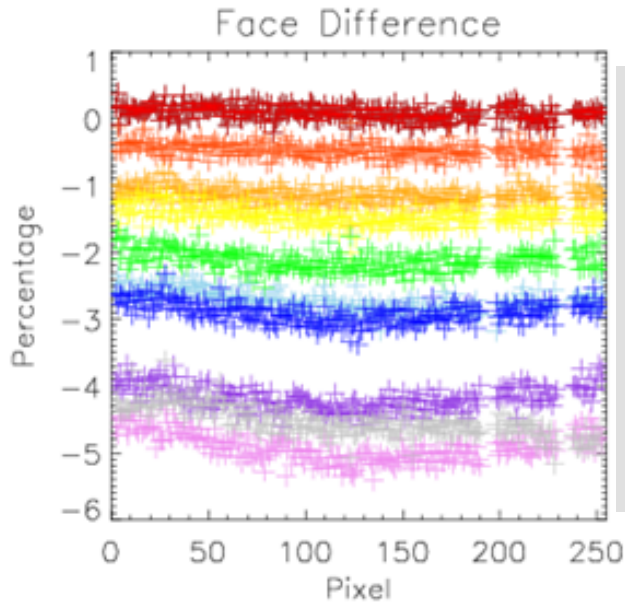


ESU

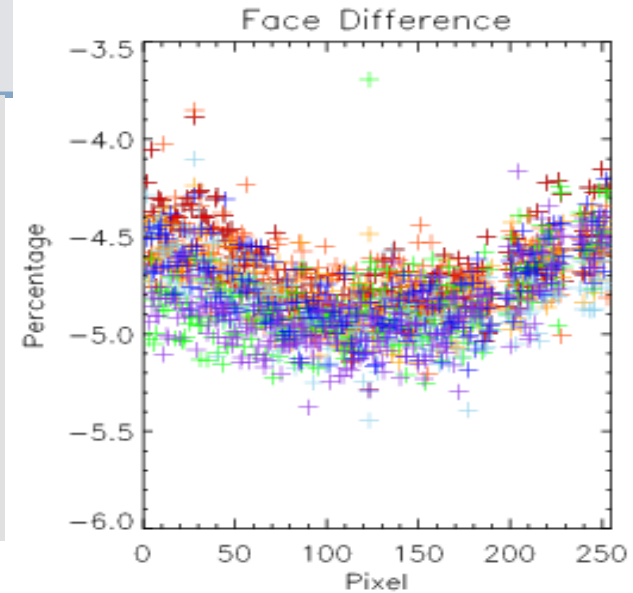


# Mirror Face Darkening on GERB-2

Mirror face differences looking at CALMON

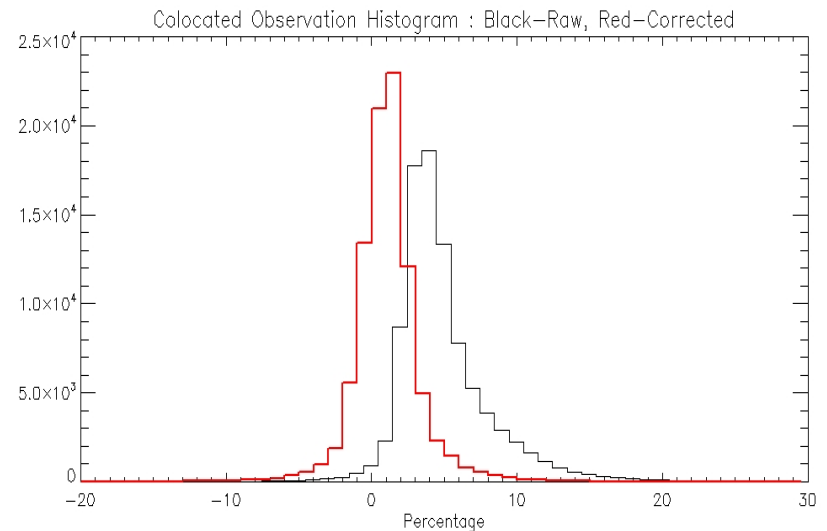
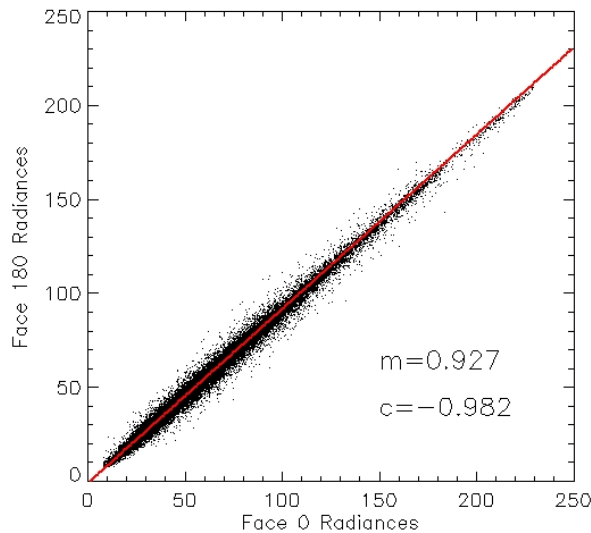


2003  
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2008  
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2014  
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2016

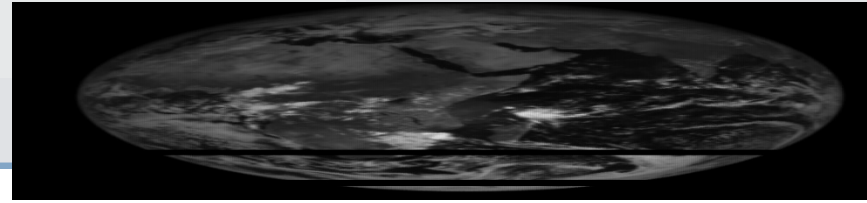


Feb 2016  
Nov 2016  
Jan 2017  
May 2017  
Oct 2017  
Jan 2018  
Apr 2018

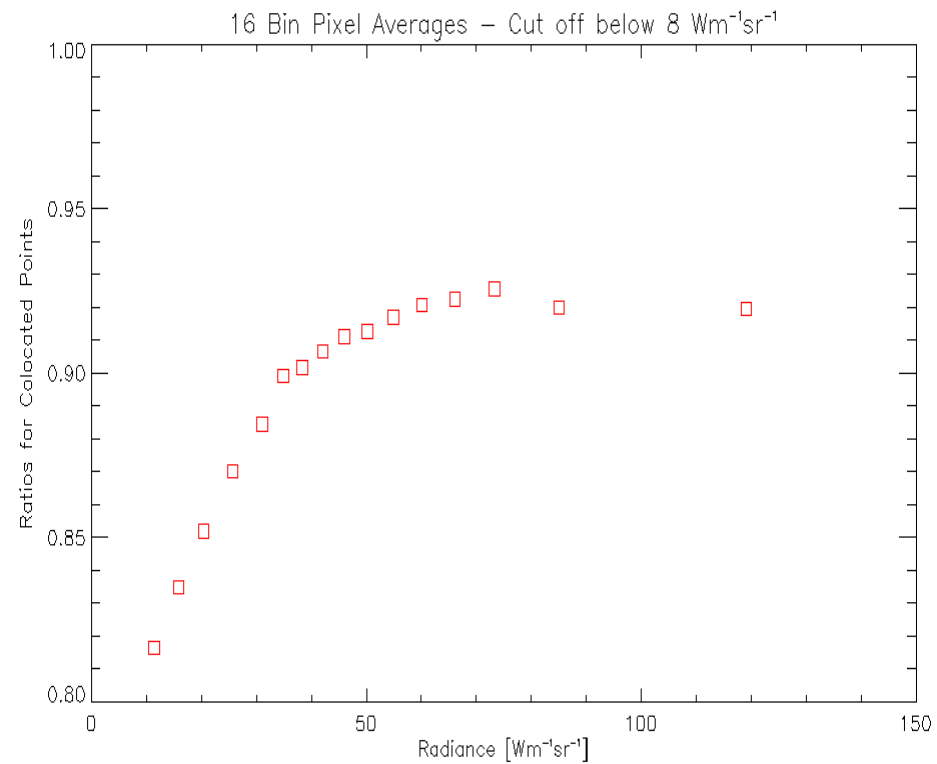
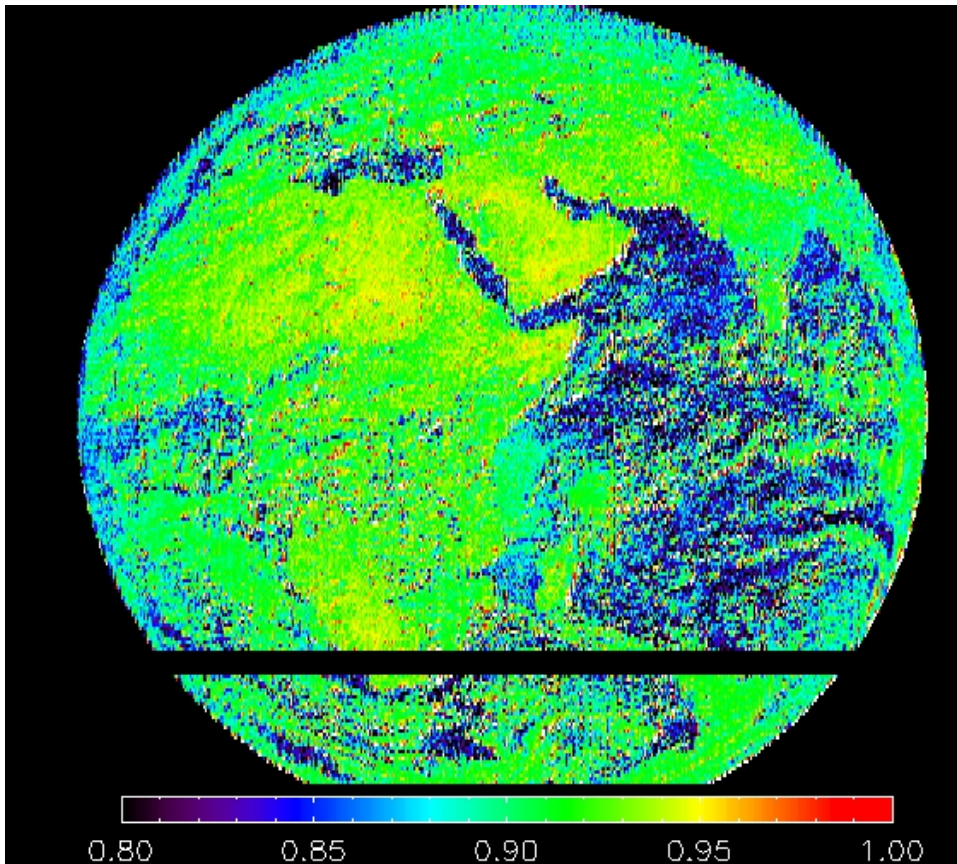
2016 Mirror face differences for Earth scenes



# Scene dependence of mirror face differences 2016



Zero step size comparison November 2016

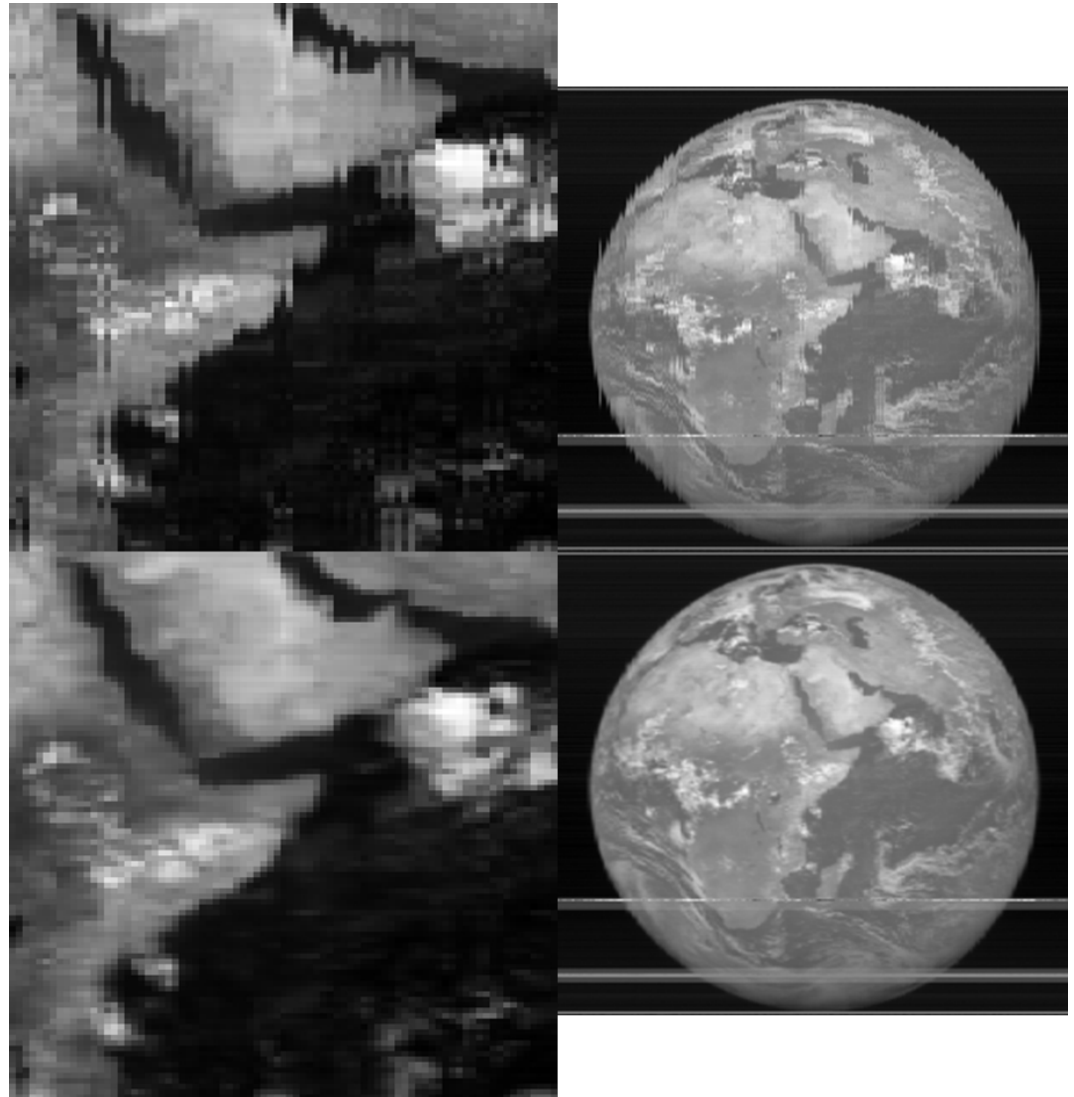


# GERB-2 TSOL Corrected Re-gridded Image

Using the TSOL correction from the EUMETSAT orbital model we can adjust column using average mirror speed.

Data is then re-gridded by interpolation to recover regular E-W pixel spacing.

In the magnified sub satellite region shown the corrective effect on coastlines and cloud fields is obvious.





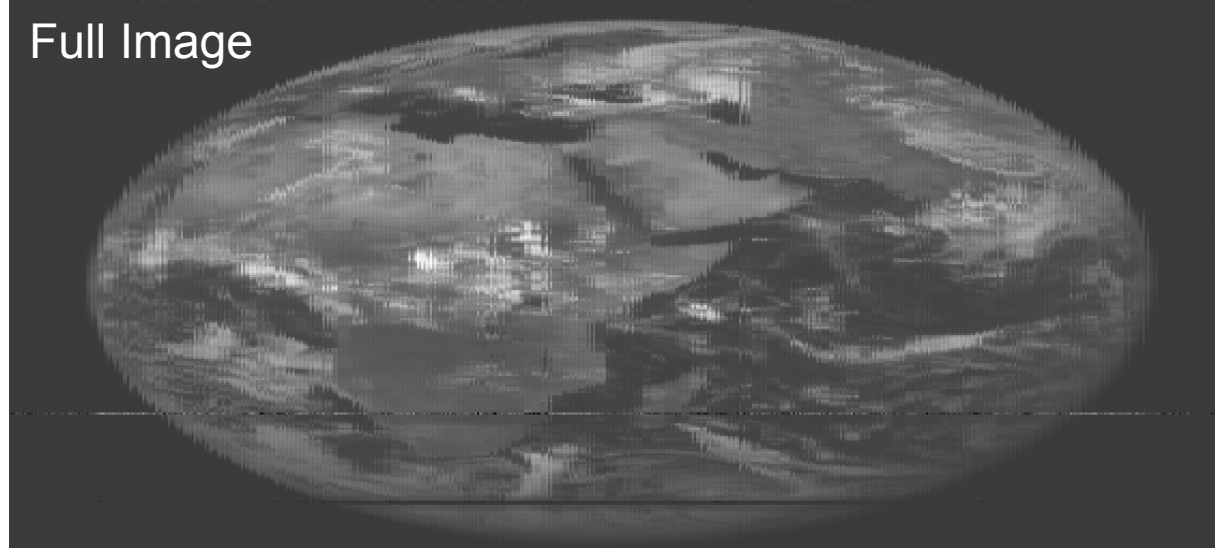
# 564 Column NORMAL Scan

In order to avoid the difficulty of interpolating a regular image using mirror sides with different properties a 564 column image acquisition has been started (9 UTC 6/6/17)

TSOL correction to locate the 282 face 0 columns and interpolation to a regular grid is proposed to regenerate a standard NORMAL image.

The disadvantage is the doubling of image gathering time.

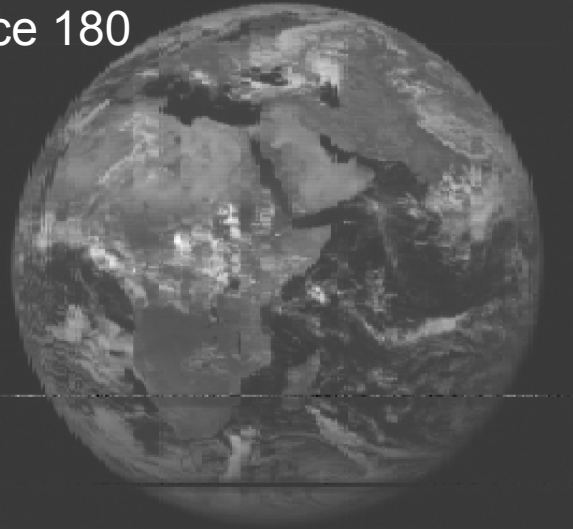
Full Image



Face 0



Face 180



# GERB-2 Conclusions

- The GERB-2 DSM is running well, since the last operations meeting daily data losses due to pointing errors are always <1% and often 0%.
- A method for locating the pointing of individual columns has been derived using the TSOL data.
- Regridding the columns evenly into a reconstructed image can be achieved by interpolation.
- Mirror face darkening has been shown to have a spectral component which will be complicate the interpolation.
- This can be avoided by collecting 282 column images on a single mirror face using the 564 column scans allowing GERB-2 to collect Indian Ocean data over the Summer.
- The correction and re-gridding process for the 564 scan has improved the images **80%** of the way to ideal in the SW channel and **65-70%** in the Total channel.

# Summary

- Four GERB instruments at different stages in their life in orbit all still able to operate. GERB 4 operating as prime at 0° and GERB 2 at 41.5°E, others in storage configuration
- Differential mirror side aging seen on GERB 2, GERB 3 and to a small extent now GERB 1. Investigations to process ongoing.
- GERB 2 operating in 564 scan which along with satellite pointing correction being investigated to enable IODC to be processed summer and winter.
- GERB mirror mechanism behavior continues to evolve over life and we have recently had need for new procedures to deal with more serious disturbances
- New drive control system of GERB 3 and GERB 4 requires different operational procedures but provides more precise pointing
- Based on GERB 1 operating experience we hope to continue GERB 4 operation into MTG era and believe we have several more years life in GERB 3 as a backup or to further the record into the future. Moving forward planning from 2023 end of mission to 2030 end of mission.